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DESIGN AND RESEARCH ON BENDING MOULD OF HIGH-STRENGTH PLATES

Abstract. *CNC bending machine is a kind of molding pressure equipment, which is widely used in the process of sheet metal bending, it can press the sheet metal into different angles and different geometric shapes. Equipped with the corresponding industrial equipment, it can also achieve stretching, punching, such as corrugation processing technology. With the development of production technology, people become more and more pursue the quality. High-strength plate tensile strength and hardness is very high, When using a common mould for bending, would first destroy the mould and can't be bending. In this paper, the initial design of high-strength plate bending mold is carried out, the 3D model of each part of the mould is established, and the simulation analysis of the stress is carried out. The bending principle of the mould and the calculation formula of the bending force are introduced, has the very important economic significance for the reasonable selection of bending mould.*

Keywords: High-strength plate; mould; Bending principle; Bending force

Introduction

High-strength plate, as generally recognized in the industry, is the plate of very high tensile strength, which at present mainly includes WELDOX high-strength structure steel plate and HARDOX wear resistant steel plate. The BW series of hot rolled wear resistant steel, independently developed by Baosteel Group, also belong to high-strength plate family. Compared to common plates, high-strength plates have some advantages, such as high strength, high hardness, and light weight, which make them increasingly used in industries that require high material performance, e.g. automobile, engineering machinery, shipbuilding, and aerospace [1; 2].

Research Objectives and Methods

With extremely high strength, higher strain hardening capacity, stronger homogeneous deformation capacity, and higher fatigue characteristics, high-strength plates have been widely used. But in the application of high-strength plates, particularly in precision manufacturing, the significant increase of their strength has brought a variety of new challenges to the forming technology and mould design. If common bending moulds are used for bending, the moulds are often damaged first, then the bending process cannot go on. Therefore, the bending mould of high-strength plates is designed and manufactured to meet this demand. Compared to common bending moulds, the bending mould of high-strength plates has the following outstanding advantages [3; 4]:

1. Upper and lower mould parts are made of low alloy high-strength structural steel, easy to machine and assemble.
2. The rounded part of the punch (upper mould) is selectively quenched to improve its surface hardness, and therefore there will be no compressive deformation occurred in that part during bending.
3. Scratch proofing design is used for the orifice of the lower mould, which can reduce damage to the steel plate surface during bending.
4. It can reach the bending capacity of 300 – 500 t/m.

A method combining theoretical design and simulation analysis will be used to design and manufacture the bending mould that meets the bending requirements for high-strength plate, reaches the bending capacity of 300 – 500 t/m, and guarantees the bending precision.

Research Process

Structural Design

Based on the preliminary design of the bending mould for high-strength plates, the following improvements are made [5], the shape of the mould as shown in Fig. 1 and Fig. 2:

1. The upper and lower mould parts are spaced and assembled by use of template. For easy processing and assembly, the template is directly cut into desired shapes by laser cutting machines.
2. Use high-hardness materials to improve the wear resistance capacity of lower mould. The orifice of the lower mould is provided with scratch proofing design

by installing two rollers, which are made of alloy round bars and difficult to wear, on each side of the V shaped groove. During the operation of bending, the two rollers will rotate as the work piece bends, so there will be no sliding friction between the work piece and the rollers, but only rolling friction, which can protect the surface of the work piece from being scratched [6];

3. Use a relatively large radius for rounded part on the upper mould, so there will be no press marks on the work piece when bending;

4. Use a larger rounded part (than the common one) on the upper mould, otherwise there will be cracks in it during bending. According to the parameters provided by the suppliers, the R should be no less than 4×s, wherein s is the thickness of the plate.

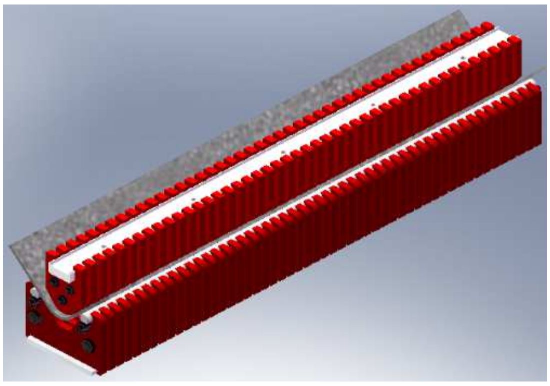

Figure 1 – Outline view of mould

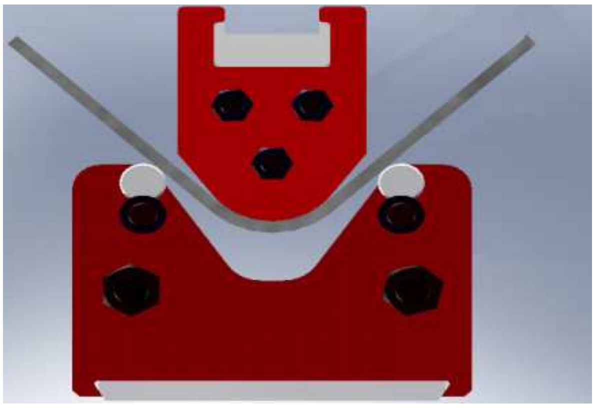

Figure 2 – Side view of mould

Bending principle

Bending modes mainly include free bending and sole pressing bending. This mould is made for common free bending, which is flexible and easy. In this bending process, the shape of the concave mould is fixed, while the plate is placed on the mould. When the sliding block of the bending machine drives the punch to move downward to bend the plate, the plate will be bent into a certain angle in the concave mould. The bending angle of the plate depends on the depth that the punch enters into the mould, so it is feasible to use a mould to bend the work piece into different angles. The bending mechanism is as shown in Fig. 3:

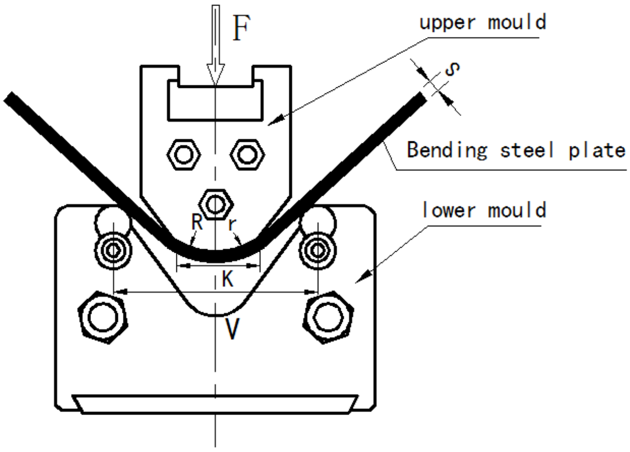

Figure 3 – Diagram of Bending principle: F – Bending force; S – Thickness of the plate; V – Opening width of the lower mould; r – The inner radius of the plate bending; K – Horizontal projection width in bending deformation area

Calculation and application scope of bending force

Bending force is an important basis for bending process design and selection of equipment and design of mould. The bending force is affected by many factors, such as material properties, shape of parts, bending method and mould structure.Fig. 3 shows the bending mechanism. In case of free bending on the common mould, the plate normally is bent into 90°, so in this paper, only the theoretic computation of the bending force for bending high-strength plate into 90°will be introduced.

The optimal width of the V shaped groove during bending is about 8 to 10 times the thickness of the plate. Too small distance between the mould orifices may result in fractures in the bending layer due to the reduced bending radius. Too large opening will reduce the bending force and the press marks, but it will increase the spring-back value. Rebound is an inevitable phenomenon in plate processing because the shape and size of bent work piece will be changed after it moves from the mould. Therefore the rebound of the plate must be considered for opening of lower mould. During bending, the value of the inner radius r of the work piece is normally equal to (0.16 – 0.17) V, so in the paper, the selected width-to-thickness ratio V/S is equal to 9 and the radius width ration r/V is equal to 0.16 [7; 8].

In the bending process, the deformation zone is in a highly plastic deformation state, and is bent into a certain angle around the center line. Apart from the area near the center line, the stress values in all other parts in the deformation zone are close to the tensile strength of the material, and the part above the center layer is compressed, while the part below the center layer is in tensile state [9; 10]. The cross section of the deformation zone and the stress distribution during bending are shown in Fig. 4.

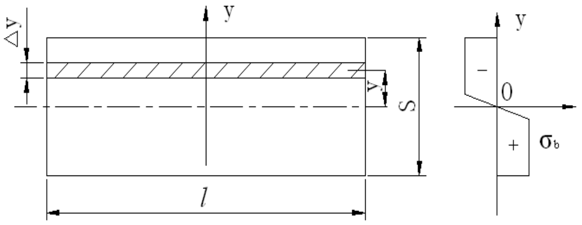

Figure 4 – Diagram of Bending Stress

The bending moment on the cross section of the deformation zone is:

$$M_1 \approx 2\int_0^{\frac{S}{2}} l\sigma_b y dy = \frac{S^2 l}{V}\sigma_b \quad (1)$$

The bending moment produced from the bending force in the deformation zone is:

$$M_2 = \frac{F}{2}\frac{V-K}{2} = \frac{F}{4}(V-K) \quad (2)$$

$M_1 = M_2$, then it can be obtained:

$$F = \frac{S^2 l}{V-K}\sigma_b \quad (3)$$

In case of bending into 90º:

$$K = \sqrt{2}(r+\frac{S}{2}) = \sqrt{2}(0.16V+\frac{V}{18}) = 0.305V \quad (4)$$

Put K into the above formula to obtain:

$$F = \frac{S^2 l}{0.695V}\sigma_b = 1.44\frac{S^2 l}{V}\sigma_b \quad (5)$$

Wherein, F – bending force, kN; S – thickness of the plate, mm; *l*- bending length, m; V – opening width of the lower mould, mm; σ_b – tensile strength of materials, MPa.

The actual bending force is higher than the theoretical one, which is due to the bending stability. When the bending force is small, the sliding block of the bending machine is subject to load and begin to vibrate; as the bending force increases, the vibration will weaken. And, the higher the tensile strength and hardness of the steel plate are, the higher the bending force it needs.

Simulation Analysis

A 3D model containing all mould parts is established in Solidworks software, and an analysis on the stress is made, as shown in Fig.5, Fig.6.

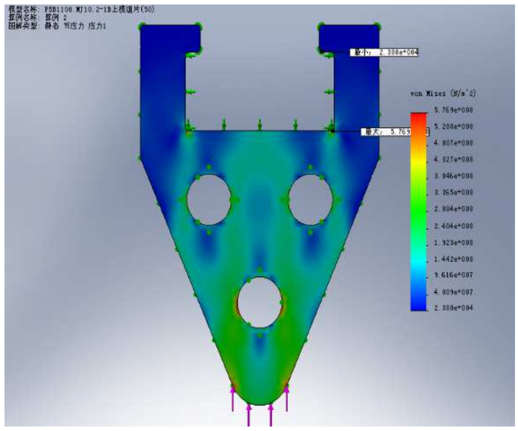

Figure 5 – Stress analysis of the upper mould

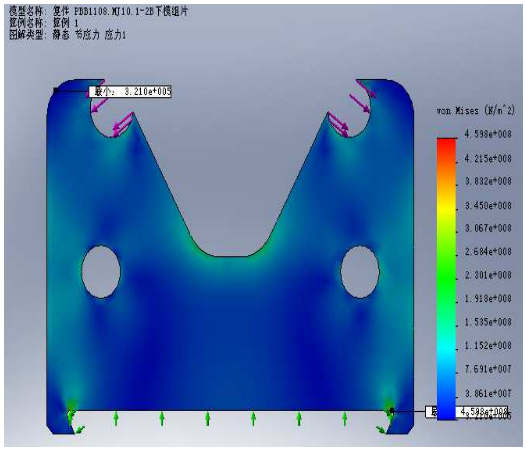

Figure 6 – Stress analysis of the lower mould

According to the analysis, from the stress diagram, it can be seen that all the stress values in the upper and lower mould parts are within the allowable range, with only relatively large localized stress. Based on the actual experiment results, there is no fatigue damage to the mould.

Conclusion

In this paper, based on the theoretical design of the bending mould, a detailed deduction and calculation of the theoretic bending force is conducted, and through the method that combines theories and simulation analysis, a mould that meets the bending requirements for high-strength plate is designed and manufactured. Also, the advantages compared with the common mould are introduced, which has an enormous economic significance for rationally selecting bending moulds.

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ПРОЕКТУВАННЯ ТА ДОСЛІДЖЕННЯ ЗГИНАННЯ ПРЕСФОРМИ ВИСОКОМІЦНИХ ПЛАСТИН

Анотація. *Гнучкий станок з ЧПУ є своєрідним пристроєм для пресування, який широко застосовується в процесі гнуття листового металу, він може вигинати металопрокат під різними кутами та створювати різні геометричні фігури. Оснащений відповідним виробничим обладнанням, він також може виконувати розтягування, штампування, наприклад, технологія обробки гофрокартону. З розвитком виробничої технології люди все більше і більше уваги приділяють питанням якості. Висока міцність на розтяг та дуже висока твердість при використанні звичайної форми для згинання спочатку зруйнують форму і не зможуть зігнути. У даній роботі виконано початковий дизайн високоміцної форми для згинання пластин, встановлено 3D-модель кожної частини прес-форми та проводиться симуляційний аналіз напруги. Впроваджується принцип згинання форми та формула розрахунку сили згинання, що має дуже важливе економічне значення для розумного відбору гнучкої форми.*

Ключові слова: високоміцна плита; цвіль; Принцип згинання; Згинання сили

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